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The Evolution of Student Interaction with an Infinitely Explorable Online Learning System

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Abstract

In this paper, we will present an analysis of the manner in which students interact with the free body diagram tool in an infinitely explorable online learning system. The Sigma Grading System (SGS), www.sigma-gs.com/SGS, provides students engineering problems in statics, fluids, mechanics of materials, and physics which can be infinitely explored. Traditional online systems use a hint based system. If a student has trouble, such systems let them ask for a hint and proceed. Instead, SGS provides the ability for the student to test intermediate steps. If a student cannot determine the value of the sin of an angle, they can first check if the angle they are using is correct. In this way, a student is free to test any and all possible intermediate steps in a problem. We will show how students evolve to take advantage of this promoting creative thinking and less reliance on formulaic learning. Specifically, as students gain confidence, they take advantage of the free body diagramming tool to explore systems. This analysis is made possible due to the fact that SGS maintains a log of student entries for each problem. The analysis also gives insight into the way students approach problems.

Introduction

Over the past decade, there has been a rapid improvement in "smart" computer tutoring systems. Computer systems are ideally suited to aid students who have difficulty visualizing structures. By allowing interaction, students may change the view angle to discern the three dimensional nature of the problem. In addition, the software may be used to guide a student through the solution process.

While students have different learning styles, and professors often have different teaching styles, it is becoming increasingly clear that effective assessment and immediate student feedback can produce beneficial results in the classroom[1]. Computer systems are ideally suited for such immediate feedback. They can also be used to present interactive case-based problems[2]. Systems have emerged which are capable of analyzing student response and providing targeted feedback to students when their response is incorrect. Systems such as ARCHIMEDES[3], Statics Tutor[4], Shaping Structures: Statics[5], BEST Statics[6], M-Model[7] and many others have emerged to provide students with modern computational learning tools[8,9]. However, as noted by St. Clair and Baker[10], there remains room for improvement. None of these software solutions provides both an online distribution mechanism and a flexible entry system capable of handling a variety of problem types and vector notation.

An informal discussion with students who were currently using online homework systems revealed that students disliked using these systems for several reasons. Students find it difficult to ask the professor questions regarding the online solution and methodology. There is no record of effort involved or of partial progress made in the solution of the problem. Determining the exact format expected by the software is difficult. An informal discussion with professors using the online software systems indicated that many professors found that scores for online homework did not correlated with student exam scores.

Software Description

The SGS system focuses on 1) providing three dimensional explorable problems, 2) providing students the ability to test an intermediate step, solution, or extraneous hypothesis related to a problem, 3) automatically grading and assessing solutions.

First, the ability to explore problems interactively in three dimensions is extremely important in an introductory course. Students who graduate will go on to design and analyze structures using 3D cad programs. Beginning early helps students to become accustomed to using such systems for visualization. The SGS system allows students to view systems in 3D, spin them, zoom etc. to get a feeling for how structures are arranged, Figure 1.

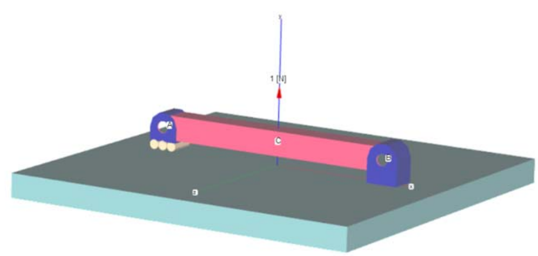


Figure 1. Three dimensional view of a simply supported beam as shown in the SGS system.

The three dimensional view also allows students to explore deeper concepts. For example, when learning mechanics, students have trouble visualizing where forces are applied. Given the truss in figure 2, a student might wonder whether the force is attached to one of the bars, or a pin. Allowing students to explode the structure quickly answers this problem and allows the student to visualize connections. They will see holes for pins, the pins themselves, and other potential connections.

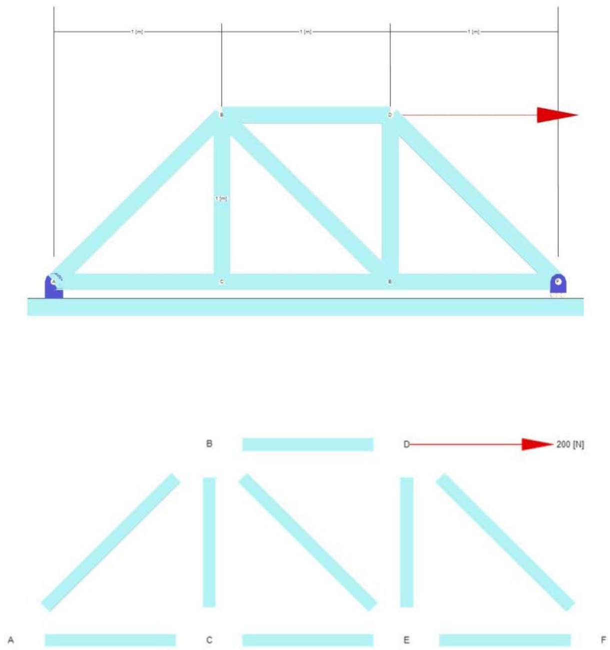


Figure 2. A truss shown in the SGS system and an exploded view of the same structure showing that the force is applied to a pin.

Allowing students to test intermediate steps also helps them to think creatively. There are many ways to arrive at an engineering solution. We want students to internalize concepts and not recipes. This system can analyze any potential mathematical statement and uses strict vector notation Figure 3.

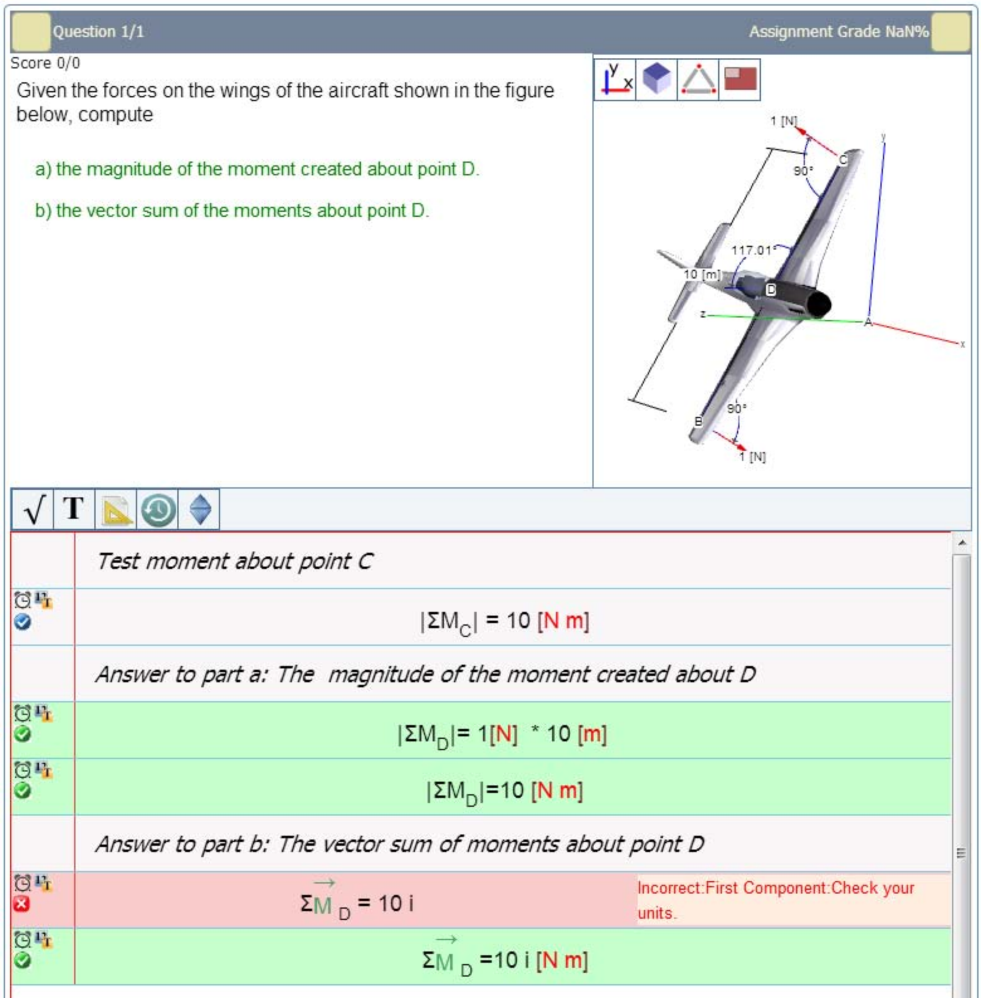


Figure 3. Typical question provided by the SGS system. Students can enter any possible intermediate step and obtain immediate feedback.

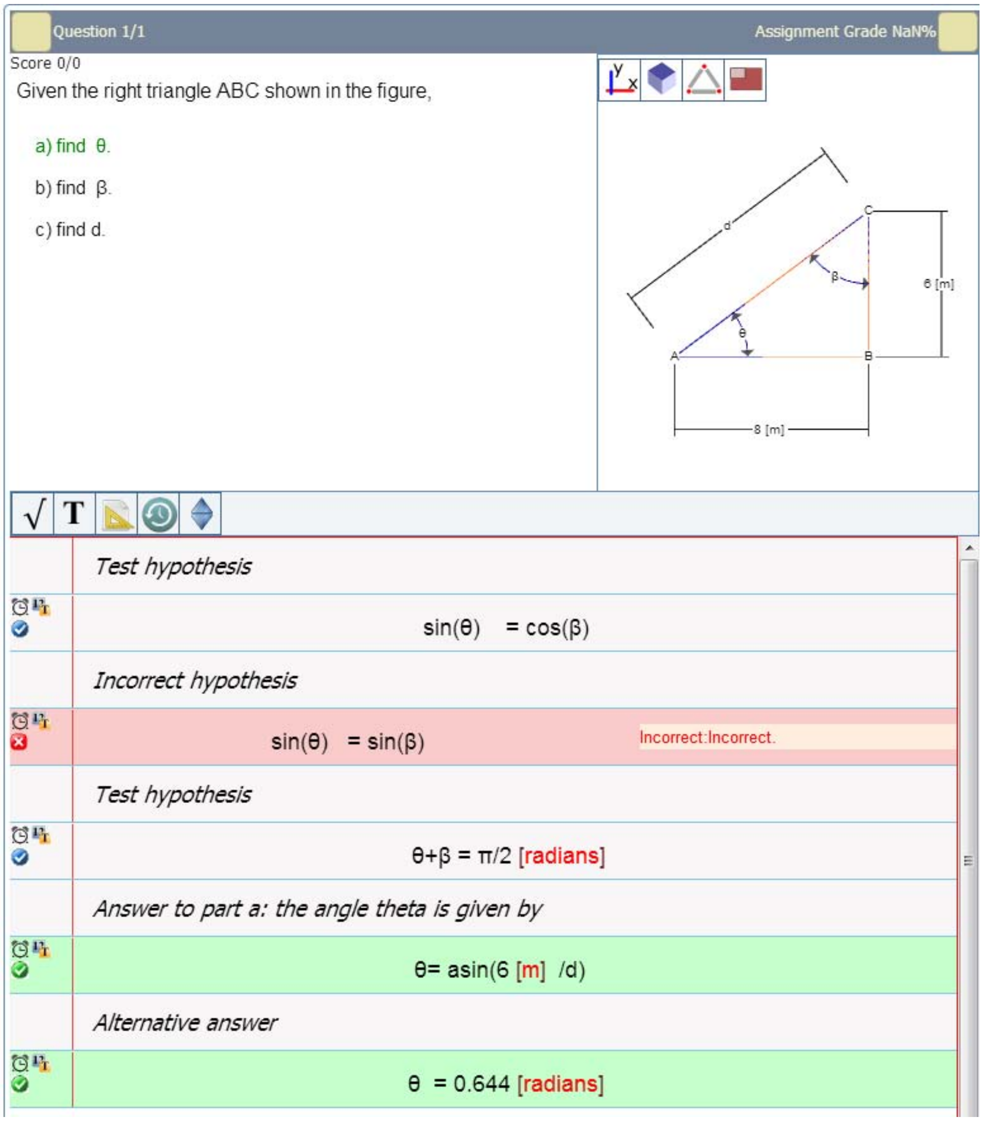
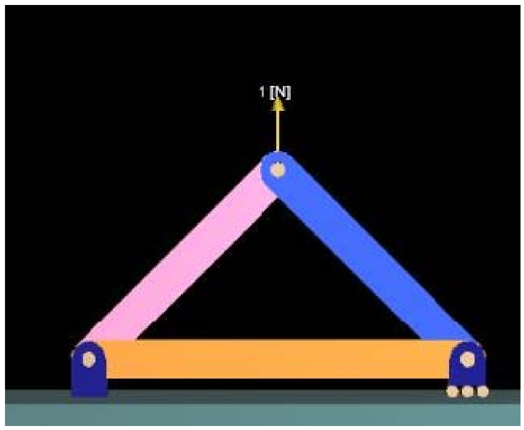


Figure 4: Sample question found in the SGS system. Students may use numerical values, symbolic variables, or any combination to specify answers or hypotheses.

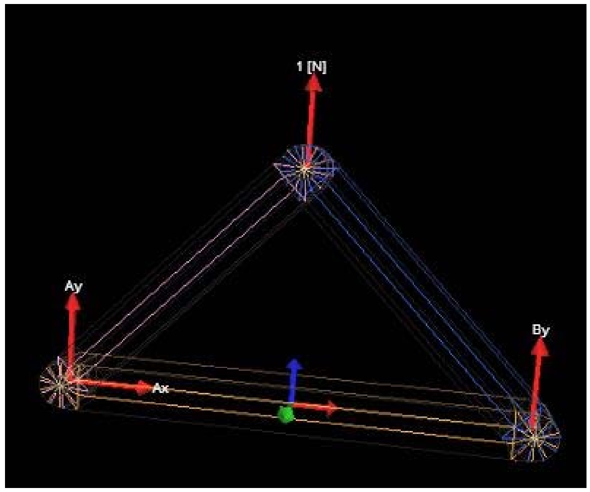
Results

This paper will focus on presenting the results of a study conducted at _______ College in the Fall semester of 2012-2013 academic year which included 12 students in an introductory engineering statics course. Students using the SGS system outperformed their peers who were not using the system by approximately one grade level[11]. However, a better understanding of the particular mechanisms is needed. In particular, we will analyze the evolution of student free body diagrams within the system to determine whether students using the system learn to take advantage of the infinity explorable nature of the problems.

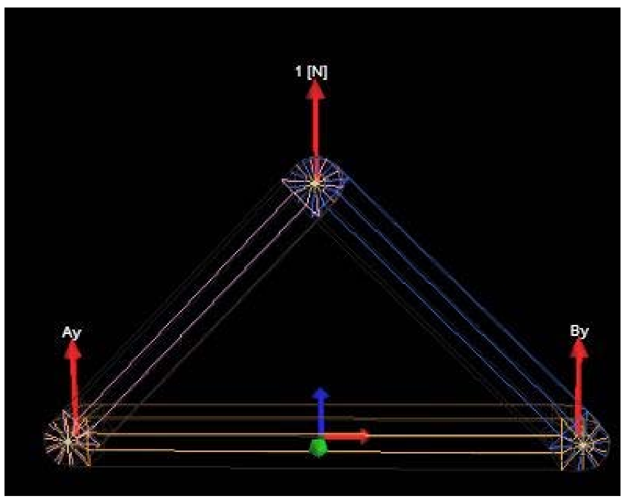
Figure 5: Example of free body diagram entry using SGS.



(a) Original figure showing a truss with a single external load of 1 N.



(b) Example of a free body diagram entered which is missing a horizontal reaction on the fixed connection. The system requires that students include the reaction and then specify that it has zero magnitude.



(c) A free body diagram which correctly specifies reactions at A and B and includes the external applied load.

Students were given homework assignments during the course of their introductory engineering statics course. These assignments contained problems which required students to produce free body diagrams. The system analyzed and graded student free body diagram entries. In addition to grading the final free body diagram, the system keeps track of the number of attempts, the types of errors, and the feedback given to students. Table 1 shows a tabulation of student responses.

	FBD A1	FBD A2	FBD A3
Number of attempts per diagram	**4.4**	**2.6**	**2.2**
Extra forces	**31%**	**46%**	**28%**
Incomplete Diagram	**55%**	**51%**	**63%**
Incorrect magnitudes	**11%**	**0%**	**5%**
Student Syntax Errors	**3%**	**2%**	**3%**

Table 1. Analysis of submitted student free body diagrams.

Students using the system quickly learned how to enter free body diagrams. The number of attempts required per free body diagram dropped from roughly 4 attempts down to 2 attempts per diagram even though the problems became more difficult. This indicates that an understanding of the mechanics of the system improve with time. Analyzing the errors shows that the most prevalent errors were incomplete diagrams and incorrect force directions. The category “Incomplete diagram” includes leaving off a required reaction force or external force. In addition, leaving off a weight or incorrectly specifying a distributed load qualifies as an incomplete diagram. “Extra forces” is used to characterize problems where the student has added extra reaction forces or external forces. The category “extra forces” also includes the misplacement of external loads. “Incorrect magnitudes” is reserved for the incorrect magnitude of an external force placed upon a diagram.

Summary

A new infinitely explorable three dimensional online learning environment has shown great promise in improving student learning outcomes[11]. The current study shows that over time students become familiar with the free body diagram entry tool. They require fewer repeated attempts to enter a diagram. This indicates an improved understanding of free body diagrams, and the mechanics of the software system. However, as the number of errors decreases the distribution of the types of errors they make remains constant. The system is currently being expanded to improve error classification. Also free body diagram errors will be collected and analyzed in real time for the instructor. This will provide the instructor with additional feedback on student learning.

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